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ABSTRACT

Refinements of work with calculator algorithms previously conducted by the author are reported. Work with "chaining" and the doing/undoing property in addition and subtraction was tested with 24 third-grade students. Results indicated the need for further instruction with both ideas. Students were able to manipulate the calculator keyboard, but had difficulty with the conceptualizations of the calculations to be executed. (MS)

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THIRD GRADE STUDENTS' PERFORMANCE ON CALCULATOR AND CALCULATOR-RELATED TASKS

by J. Fred Weaver

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July 1979

Wisconsin Research
and Development Center
for Individualized Schooling

Technical Report No. 498

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by

J. Fred Weaver

Report from the Project on
Studies in Mathematics

Thomas A. Romberg, John G. Harvey, and J. Fred Weaver
Faculty Associates

Wisconsin Research and Development Center
for Individualized Schooling
The University of Wisconsin
Madison, Wisconsin

July 1979

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The following explorations were based on refinements of work reported in Project Paper 76-1 (1976a) and Project Paper 76-3 (Weaver, 1976b).

Problem 1

Students' calculator work included attention to "chaining": solving exemplars of the forms

1. $a + b + c = \boxed{n}$
2. $a - b - c = \boxed{n}$
3. $a + b - c = \boxed{n}$
4. $a - b + c = \boxed{n}$

where a, b, c were whole numbers (members of set W) so that subtraction was always possible within W.

The following calculator algorithm was used (although not explicitly formulated as such for students), with Step 4 eventually eliminated and the intermediate result displayed when the operation key at Step 5 is depressed. (∇ is + or -; § is + or -.)

STEP	INPUT	KEY	OUTPUT
1	a		
2		∇	
3	b		
4		=	$a \nabla b$
5		§	
6	c		
7		=	n

Figure 1. Calculator algorithm.

Quite deliberately, during the course of instruction no particular attention was given to comparing the magnitude of n with the magnitude of a for specific exemplars. To what extent were students able to make such comparisons more or less "spontaneously," especially for exemplars of types 3 and 4,--*just by "looking at" exemplars, without doing any calculations?*

In an attempt to answer this question, a 15-item instrument was constructed (see Appendix A), with three preliminary nonscored items used as samples to introduce students to item nature, format, and response mode. This instrument is identified as Test 1.

Findings

Test 1 was administered to 24 third-grade students on March 1, 1977 and resulted in the distribution of correct responses summarized in Table 1.

Table 1

Distribution of Correct Responses: Test 1

Number of correct responses	Frequency
15	1
14	
13	
12	3
11	3
10	4
9	4
8	5
7	
6	1
5	3
Total	24
Mean: 9.2 (61.4%)	
"Not Sure" Responses: 18.9%	

No differential performance effects of any consequence were observed in relation to exemplar type: for type 3 exemplars, 59.7% of students' responses were correct; for type 4 exemplars, 63.9% of students' responses were correct.

Without regard for exemplar type, the relative magnitudes of b and c appeared to have some bearing upon students' performance levels:

for exemplars in which $b > c$, 66.7% of students' responses were correct;

for exemplars in which $b = c$, 60.4% of students' responses were correct; and

for exemplars in which $b < c$, 57.6% of students' responses were correct.

The preceding findings suggest that for the students in this sample, most were not able to spontaneously judge the relative magnitudes of and for type-3 and type-4 exemplars (of the kind included in Test 1) with any high degree of consistency. Explicit instruction pertaining to this ability appeared to be necessary.

Test 2 (Appendix B) consists of two distinct parts intended to answer two quite different questions. Both parts of the test were administered on the same day, March 29, 1977, with one of the 24 students absent.

Problem 2.1

Shortly after the administration of Test 1, students used their calculators with exemplars of the following types (contrived so that subtraction was always possible within the set of whole numbers)

$$a + b - b = ?$$

$$a - b + b = ?$$

in an attempt to "discover" the doing/undoing property pertaining to addition and subtraction:

$$a + b - b = a,$$

$$a - b + b = a.$$

An 18-item instrument (Test 2, Part 1) was constructed in accord with the matrix displayed as Table 2 in an attempt to ascertain:

1. how well students could respond *without using calculators* to exemplars of the doing/undoing property in the same form that was used during instruction (N-position 1, Conditions 1, 2, 3);

2. how well students would respond *without using calculators* to exemplars of the doing/undoing property presented in a different form than was used during instruction (N-positions 2, 3, 4; Conditions 1, 2, 3); and

3. how well students would respond *without using calculators* to nonexemplars of the doing/undoing property that superficially, at least, resembled exemplars of that property.

Table 2

Item Types for Test 2, Part 1

Condition	N-position			
	1 a ▽ b △ b = [N]	2 a ▽ b △ [N] = a	3 a ▽ [N] △ b = a	4 [N] ▽ b △ b = a
1 b > a	W * a + b - b = [N]	F a + b - [N] = a	S a + [N] - b = a	Q [N] + b - b = a
2 b < a	H a + b - b = [N]	Y a + b - [N] = a	J a + [N] - b = a	L [N] + b - b = a
3 b < a	R a - b + b = [N]	M a - b + [N] = a	X a - [N] + b = a	E [N] - b + b = a
4 Non-prop	K a - b + a = [N]	P a - b + [N] = b	G a - [N] + a = b	Z [N] - a + b = a

*This (and other) capital letter(s) identifies the particular test item for which the exemplar is of the type associated with this cell.

Gross overall performance on Test 2, Part 1 is summarized in Table 3. More specific aspects of performance are summarized in Table 4, from which several observations appear to be valid even though no formal hypotheses were tested statistically:

1. Performance was not comparable across all cells of the matrix.

2. Among the exemplars of item types that had been "taught," performance on R was nontrivially lower than performance on W or H.

Table 3

Distribution of Correct Responses: Test 2, Part 1

Number of correct responses	Frequency
15	2
14	1
13	1
12	5
11	3
10	2
9	1
8	6
7	
6	
5	1
4	
3	
2	1
Total	23
Mean: 10.2	

3. Performance on items with N in "untaught positions was lower than that on items taught with N in the canonical position.

4. Lowest performance levels were observed on those items that closely resembled, but were *not* exemplars of the doing/undoing property.

It was concluded that students had not "mastered" the property in question, and that further instruction was necessary if they were to "comprehend" the property.

Table 4

Percent of Correct, Incorrect, and "Not Sure" Responses

Test 2, Part 1

Condition	N-position 1 a ▽ b △ b = [N]	N-position 2 a ▽ b △ [N] = a	N-position 3 a ▽ [N] △ b = a	N-position 4 [N] ▽ b △ b = a	
1 b > a	W 87.0% 13.0% 0.0%	F 69.6% 8.7% 21.7%	S 47.8% 26.1% 26.1%	Q 73.9% 8.7% 17.4%	69.6% 14.1% 16.3%
2 b < a	H 91.3% 0.0% 8.7%	Y 87.0% 8.7% 4.3%	J 65.2% 26.1% 8.7%	L 73.9% 17.4% 8.7%	79.3% 13.0% 7.6%
3 b < a	R 69.6% 13.0% 17.4%	M 65.2% 17.4% 17.4%	X 52.2% 30.4% 17.4%	E 47.8% 39.1% 13.0%	58.7% 25.0% 16.3%
4 Non-prop.	K 60.9% 30.4% 8.7%	P 39.1% 43.5% 17.4%	G 47.8% 21.7% 30.4%	Z 39.1% 17.4% 43.5%	46.7% 28.3% 25.0%
	77.2% 14.1% 8.7%	65.2% 19.6% 15.2%	53.3% 26.1% 20.7%	58.7% 20.7% 20.7%	63.6% 20.1% 16.3%

Problem 2.2

For the operations of addition and subtraction:

How well had students "mastered" the mechanics of keyboard manipulation of their calculators for "chaining" exercises involving three numbers and two operations?

How well were students able to use their calculators for other three-number, two-operation calculations in which operations were not symbolized in conventional form but were explicit or implicit in verbal expressions or words used in formulating the exercises?

In an attempt to answer these questions, Test 2, Part 2 was administered to students immediately after they completed Test 2, Part 1 (see Appendix B). Items a through d of Test 2, Part 2 pertained to the first of the preceding two questions; items e through h, to the second of the two questions.

Table 5 displays a two-way frequency distribution of correct responses for each set of four items.

The mean number of correct responses for items a through d was 3.7 (i.e., 92.4% of the maximum score of 4); the mean number of correct responses for items e through h was 1.6 (i.e., 39.1% of the maximum score of 4); and the mean number of correct responses on Test 2, Part 2 as a whole was 5.3 (or 65.8% of the maximum score of 8).

Table 6 summarizes the percent of correct responses for each of the eight items. It is evident from Tables 5 and 6 that:

1. a high level of proficiency was demonstrated by students when manipulating the calculator keyboard for the chaining items a through d;

2. performance on items f, g and h was a much different matter.

Table 5

Two-way Frequency Distribution of Correct Responses:

Test 2, Part 2

		Items e, f, g, h				
	Number of correct responses	3	2	1	0	Σ
Items a, b, c, d	4	3	5	7	2	17
	3		3	2		5
	2		1			1
	Σ	3	9	9	2	23

Admittedly, no particular practice had been provided previously with exercises phrased as were e through h. Although students were familiar with the terms "add," "subtract," and "sum," students were not very able to "spontaneously" interpret them properly within the context of items f, g, and h in particular. It was clear from an examination of student papers that the difficulty was not in erratic calculator-keyboard manipulation, but in conceptualizations of the calculations to be executed.

Table 6

Percent of Correct Responses: Test 2, Part 2

a. 384 + 95 + 726 = ?	95.7%
b. 713 - 89 - 526 = ?	95.7%
c. 64 + 978 - 805 = ?	91.3%
d. 531 - 472 + 680 + ?	87.0%
e. To the sum of 429 and 384 add 567.	87.0%
f. Subtract 258 from the sum of 307 and 694.	47.8%
g. Subtract the sum of 573 and 189 from 841.	21.7%*
h. From 1212 subtract the sum of 123 and 321.	0.0%*
All 8 items:	

*7 of the 23 students (30.4%) omitted this item.

Problem 3

At the end of the school year, how well were the third-grade students able to do relatively routine calculations using their calculators?

Although the performance on Test 2, Part 2 had been quite high for items a, b, c, and d, multiplication was introduced subsequent to the time that Test 2 was administered.

Test 3, therefore, was prepared and administered May 10, 1977 (see Appendix C). Six of the items were in the conventional horizontal or equation format that was emphasized in the calculator work. Four of the items were in a vertical format, familiar to students in connection with pencil-and-paper calculation, but given little attention in connection with calculator work. The last "Secret Number" item was in unfamiliar format in which each student selected a secret number, executed the chaining specified, and then individually showed the teacher the result (but not the secret number). If a student's chaining was applied correctly to the chosen secret number n, the result would be 100n - 1, from which the teacher could "magically" tell a student the starting secret number.

Table 7 summarizes the percent of correct responses on Test 3. On the six familiar-format items collectively, 92.4% of the student responses were correct; on the remaining five items, 93.3% of the student responses were correct; and for the test as a whole, 92.8% of the the student responses were correct.

Twelve of the 24 students responded correctly to all 11 items; eight students responded correct to 10 of the items; two students responded correctly to nine of the items; and one student responded correctly to

Table 7

Percent of Correct Responses: Test 3

825 - 459 =	100.0%
4 x 78 =	91.7%
ADD: 697 + 548	91.7%
SUBTRACT: 903 - 256	95.7%
614 - 348 + 567 =	83.3%
ADD: 475 + 369 + 698	87.5%
186 + 734 - 342 =	83.3%
1003 - 425 -286 =	100.0%
MULTIPLY: 6 x 37	100.0%
796 + 845 =	95.8%

SECRET NUMBER item: 91.7%

eight and seven of the items. Thus, only 8% of the students responded correctly to less than 80% of the items.

Student performance was encouragingly high for the kinds of calculator manipulation sampled by the Test 3 items.

References

Weaver, J. F. Calculator-influenced explorations in school mathematics: Number sentences and sentential transformations I, II (Project Paper 76-1). Madison: Wisconsin Research and Development Center for Cognitive Learning, January 1976. (a)

Weaver, J. F. Calculator-influenced explorations in school mathematics: A further investigation of third-grade pupils' performance on open addition and subtraction sentences (Project Paper 76-3). Madison: Wisconsin Research and Development Center for Cognitive Learning, April 1976. (b)

Appendix A

Test 1

NAME _____

Draw a ring around your answer for ?

A.	249 - 0 = ?	MORE THAN 249	EXACTLY 249	LESS THAN 249	NOT SURE
B.	596 + 213 + 784 = ?	MORE THAN 596	EXACTLY 596	LESS THAN 596	NOT SURE
C.	951 - 487 - 326 = ?	MORE THAN 951	EXACTLY 951	LESS THAN 951	NOT SURE

DON'T GO ON!

D. 493 + 752 - 816 = ?

MORE THAN 493 | EXACTLY 493 | LESS THAN 493 | NOT SURE

E. 159 - 159 + 874 = ?

MORE THAN 159 | EXACTLY 159 | LESS THAN 159 | NOT SURE

F. 861 + 439 - 725 = ?

MORE THAN 861 | EXACTLY 861 | LESS THAN 861 | NOT SURE

G. 653 - 492 + 653 = ?

MORE THAN 653 | EXACTLY 653 | LESS THAN 653 | NOT SURE

H. 368 + 942 - 942 = ?

MORE THAN 368 | EXACTLY 368 | LESS THAN 368 | NOT SURE

J. 294 + 836 - 157 = ?

MORE THAN 294 | EXACTLY 294 | LESS THAN 294 | NOT SURE

K. 915 - 915 + 362 = ?

MORE THAN 915 | EXACTLY 915 | LESS THAN 915 | NOT SURE

L. 681 + 394 - 394 = ?

MORE THAN 681 | EXACTLY 681 | LESS THAN 681 | NOT SURE

M. 764 - 182 + 539 = ?

MORE THAN 764 | EXACTLY 764 | LESS THAN 764 | NOT SURE

N. 925 + 386 - 925 = ?

MORE THAN 925 | EXACTLY 925 | LESS THAN 925 | NOT SURE

P.	748 + 519 - 263 = ?	MORE THAN 748	EXACTLY 748	LESS THAN 748	NOT SURE
Q.	931 - 467 + 467 = ?	MORE THAN 931	EXACTLY 931	LESS THAN 931	NOT SURE
R.	629 + 843 - 629 = ?	MORE THAN 629	EXACTLY 629	LESS THAN 629	NOT SURE
S.	812 - 674 + 359 = ?	MORE THAN 812	EXACTLY 812	LESS THAN 812	NOT SURE
T.	555 + 555 - 555 = ?	MORE THAN 555	EXACTLY 555	LESS THAN 555	NOT SURE

Appendix B

Test 2

Test 2, Part 1

NAME _____

For each sentence, draw a ring around your answer.

WHAT NUMBER IS [N] ?

A.	[N] - 400 = 0.	400	0	SOME OTHER NUMBER	NOT SURE
B.	100 x [N] = 0.	100	0	SOME OTHER NUMBER	NOT SURE
C.	300 + 600 = [N].	300	600	SOME OTHER NUMBER	NOT SURE

WHAT NUMBER IS [N] ?

E.	[N] - 584 + 584 = 650.	584	650	SOME OTHER NUMBER	NOT SURE
F.	392 + 847 - [N] = 392.	392	847	SOME OTHER NUMBER	NOT SURE
G.	921 - [N] + 921 = 438.	921	438	SOME OTHER NUMBER	NOT SURE
H.	734 + 576 - 576 = [N].	734	576	SOME OTHER NUMBER	NOT SURE

WHAT NUMBER IS [N]?

J.	642 + [N] - 498 = 642.	642	498	SOME OTHER NUMBER	NOT SURE
K.	715 - 469 + 715 = [N].	715	469	SOME OTHER NUMBER	NOT SURE
L.	[N] + 247 - 247 = 863.	247	863	SOME OTHER NUMBER	NOT SURE
M.	902 - 654 + [N] = 902.	902	654	SOME OTHER NUMBER	NOT SURE

WHAT NUMBER IS [N] ?

P.	643 - 187 + [N] = 187	643	187	SOME OTHER NUMBER	NOT SURE
Q.	[N] + 936 - 936 = 275.	936	275	SOME OTHER NUMBER	NOT SURE
R.	824 - 269 + 269 = [N].	824	269	SOME OTHER NUMBER	NOT SURE
S.	518 + [N] - 694 = 518.	518	694	SOME OTHER NUMBER	NOT SURE

WHAT NUMBER IS [N] ?

w.	486 + 759 - 759 = [N].	486	759	SOME OTHER NUMBER	NOT SURE
x.	741 - [N] + 397 = 741.	741	397	SOME OTHER NUMBER	NOT SURE
y.	927 + 385 - [N] = 927.	927	385	SOME OTHER NUMBER	NOT SURE
z.	[N] - 324 + 702 = 324.	324	702	SOME OTHER NUMBER	NOT SURE

Test 2, Part 2

30

USE YOUR CALCULATOR

a. 384 + 95 + 726 = ? . . . . . _____

b. 713 - 89 - 526 = ? . . . . . _____

c. 64 + 798 - 805 = ? . . . . . _____

d. 531 - 472 + 680 = ? . . . . . _____

e. To the sum of 429 and 384 add 567. _____

f. Subtract 258 from the sum of 307 and 694. _____

g. Subtract the sum of 573 and 189 from 841. _____

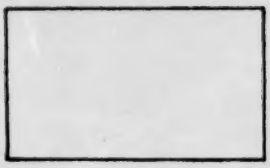
h. From 1212 subtract the sum of 123 and 321. _____

Appendix C

Test 3

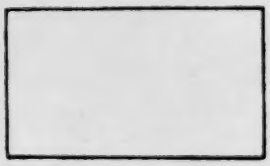
NAME _____

USE YOUR CALCULATOR FOR EACH PROBLEM. WRITE THE ANSWERS IN THE BOXES.

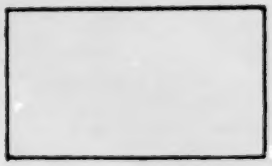
825 - 459 = 

4 x 78 =

ADD: 697
548



SUBTRACT: 903
256



614 - 348 + 567 =

ADD: 475
369
698

186 + 734 - 342 =

1003 - 425 -286 =

MULTIPLY: 6
37

796 + 845 =

NAME 34 _____

SECRET NUMBER:

x

25

+

71

-

46

x

4

-

101

=

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